CrIS Full Spectral Resolution Test Results

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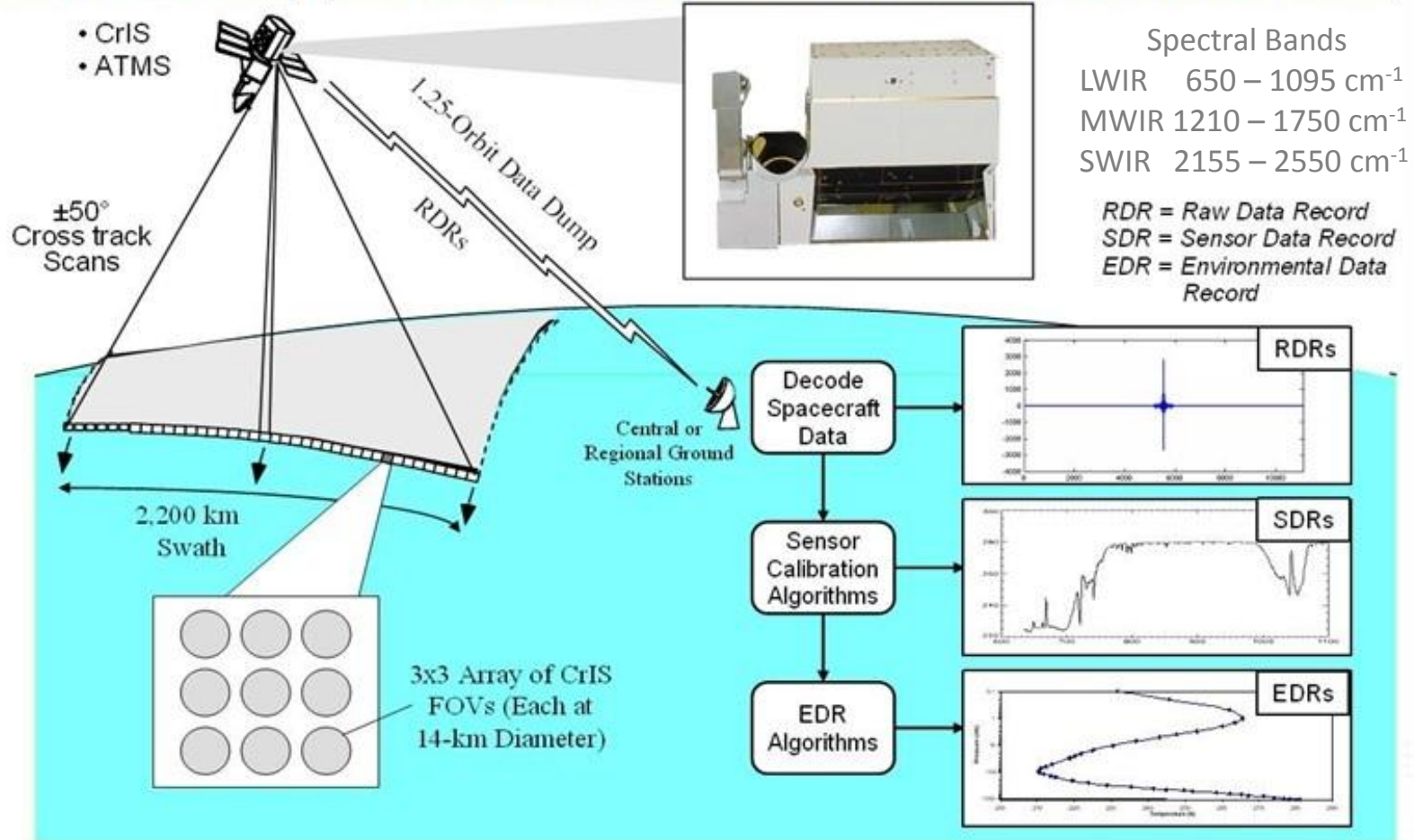
Outline

› **Introduction to CrIS and spectral resolution of a Michelson interferometer**

› **Motivation for using full spectral resolution**

› **Full spectral resolution test results**

› **Truncating full resolution interferograms to be compatible with existing spectral processing software**
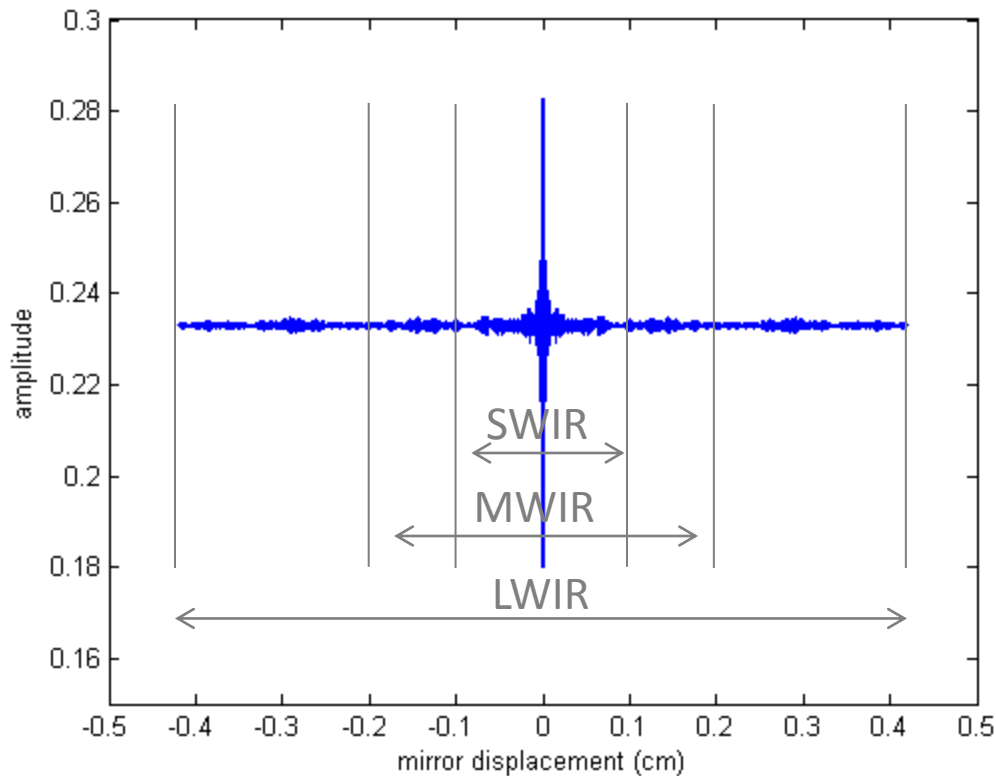
› **Conclusions**

CrIS Measurement Concept

Mission Overview

CrIS Mission: Construct Vertical Profiles of Temperature, Moisture, and Pressure (EDRs)

- CrIS
- ATMS

±50° Cross track Scans

1.25-Orbit Data Dump

RDRs

2,200 km Swath

3x3 Array of CrIS FOVs (Each at 14-km Diameter)

Central or Regional Ground Stations

Spectral Bands
LWIR   650 – 1095 cm^{-1}
MWIR 1210 – 1750 cm^{-1}
SWIR   2155 – 2550 cm^{-1}

RDR = Raw Data Record
SDR = Sensor Data Record
EDR = Environmental Data Record

Decode Spacecraft Data → RDRs

Sensor Calibration Algorithms → SDRs

EDR Algorithms → EDRs

Image courtesy of ITTExelis

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Current CrIS Spectral Resolution

Spectral Resolution

SWIR	2.5 cm^{-1}
MWIR	1.25 cm^{-1}
LWIR	0.625 cm^{-1}

> **For a Michelson interferometer, spectral resolution is determined by the length of the scan**

Full CrIS Spectral Resolution Possible

- **The length of the interferometer scan is set by the LWIR band**
- **Reduced spectral resolution for the MWIR and SWIR bands was due to perceived bandwidth consideration**
  - Simulations suggested small impact on EDR core products
- **Electronics systems have progressed considerably since CrIS was designed**
- **Full spectral resolution for the MWIR and SWIR could be increased with minimal system changes**
  - No changes to hardware or flight software needed
  - Requires only command and table upload changes
- **Full CrIS spectral resolution demonstrated by test**
  - PCE2 electronics simulator test at ITTExelis
  - Demonstrated at spacecraft-level thermal vacuum test at Ball Aerospace

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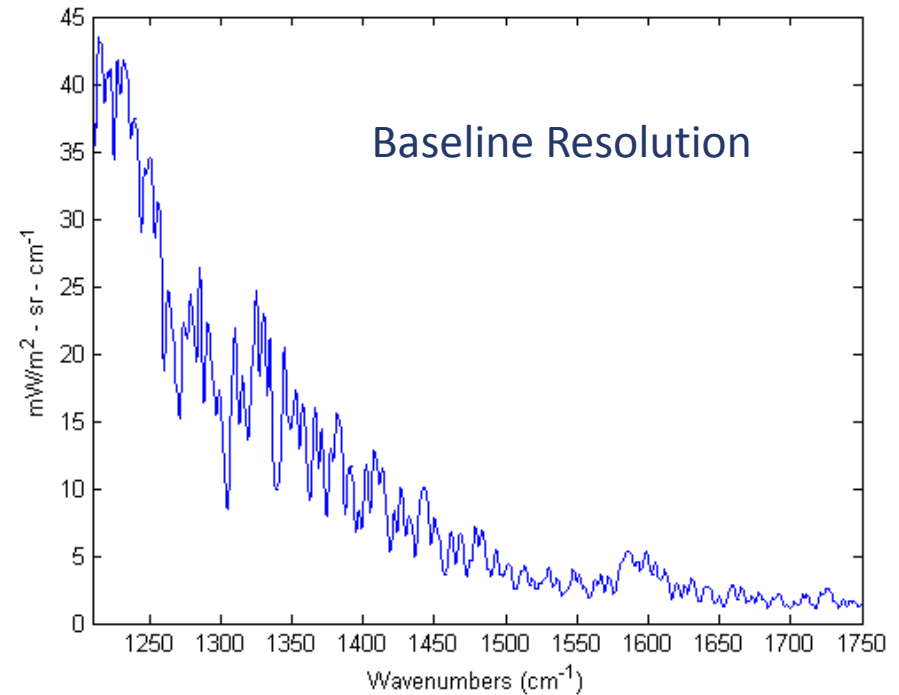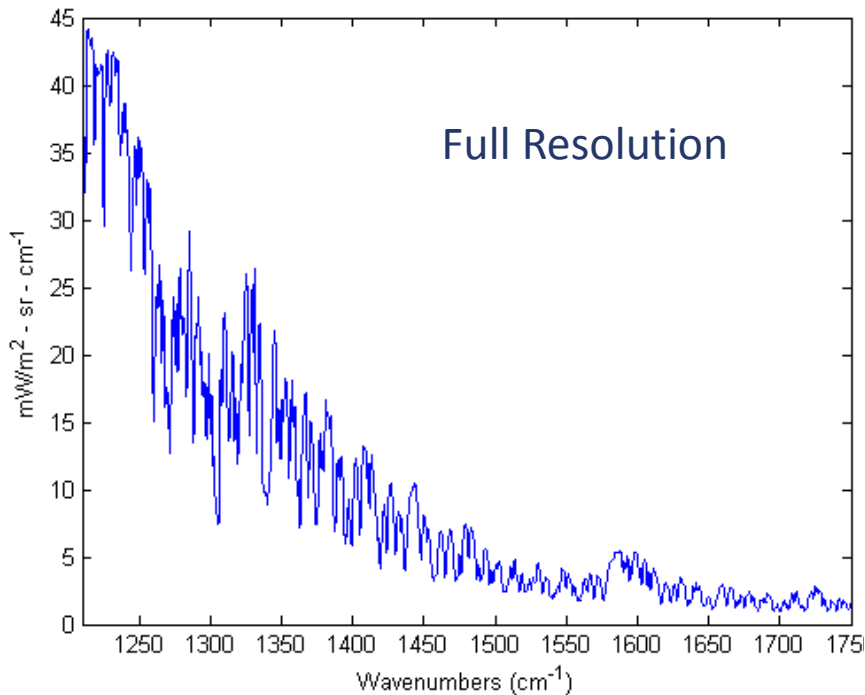Utah State University Research Foundation

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Benefits of Full Spectral Resolution

› **SWIR band cannot be spectrally calibrated in present configuration. Must use pre-flight spectral calibration.**

- Uncalibrated SWIR could make important 4.3-µm CO_2 R-branch unusable for some applications

- Cannot use 4.3-µm CO_2 R-branch for spectral calibration since impossible to separate radiometric from spectral contributions

- With full interferogram, high-altitude CO_2 lines and CO lines appear that allow spectral calibration independent of radiometric calibration

› **Carbon monoxide cannot be detected with present configuration. Time series from AIRS (and MOPITT) from EOS platforms will cease without this change. Important for global chemistry trending.**

› **Lowers ground thermal vacuum testing risk**

- CO can be used for spectral calibration, easy gas to handle

- Would allow ɪᴛᴛExelis to stop using HBr for SWIR spectral calibration. Highly corrosive and puts some of the TVAC instrumentation at risk. In early testing, HBr resulted in damage to gas cell that put TVAC instrumentation at risk.
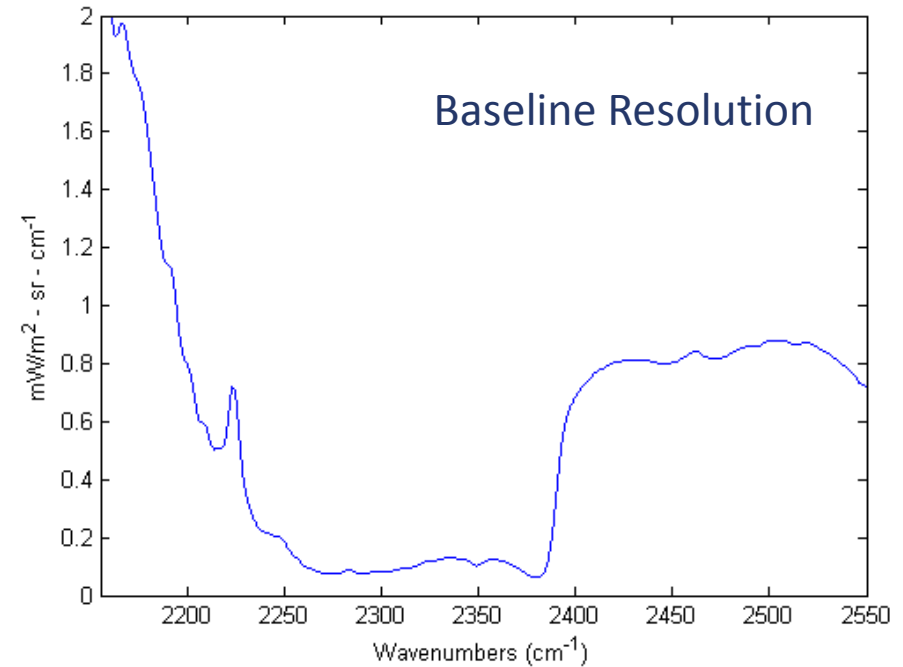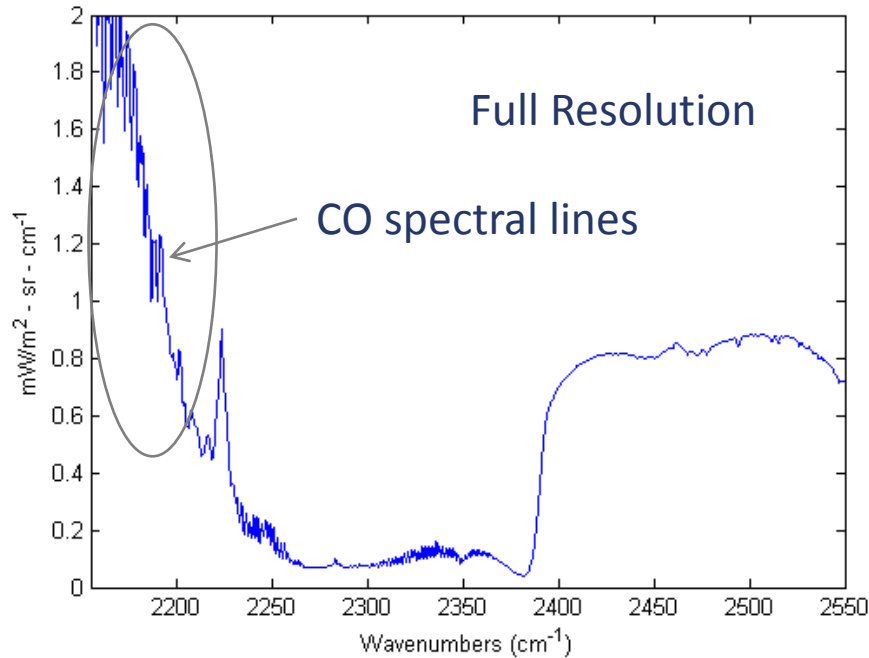
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MWIR Simulated Atmospheric Spectrum

Full Resolution

Baseline Resolution

› **Additional spectral details visible**

› **MODTRAN 5 Standard Atmosphere calculated at 0.2 cm^{-1} resolution**

› **Resolution reduced to 1.25 cm^{-1} for baseline, 0.625 cm^{-1} for full**

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SWIR Simulated Atmospheric Spectrum

Full Resolution

CO spectral lines

Baseline Resolution

› **Atmospheric spectral lines are resolved**

› **Resolution reduced to 2.5 cm^{-1} for baseline, 0.625 cm^{-1} for full resolution**

› **MODTRAN 5 Standard Atmosphere calculated at 0.2 cm^{-1} resolution**

Full Spectral Resolution Test Performed at ɪᴛᴛExelis

> **Used PCE2 electronics simulator with signal generator for detector signals**

> **Showed CrIS can output full resolution data in all bands with no hardware or flight software changes**

> **Only simple command uploads necessary to change configuration to full resolution**

> **Data bandwidth increased by 61% as expected**

> **Power increased by 1.1 W (small when compared to the 6.7 W power margin for FM1)**

> - Because longer interferograms cause signal processor FPGAs to consume more power, this power increase is as expected

> **No data dropouts or other data problems**

Higher Spectral Resolution Demonstrated
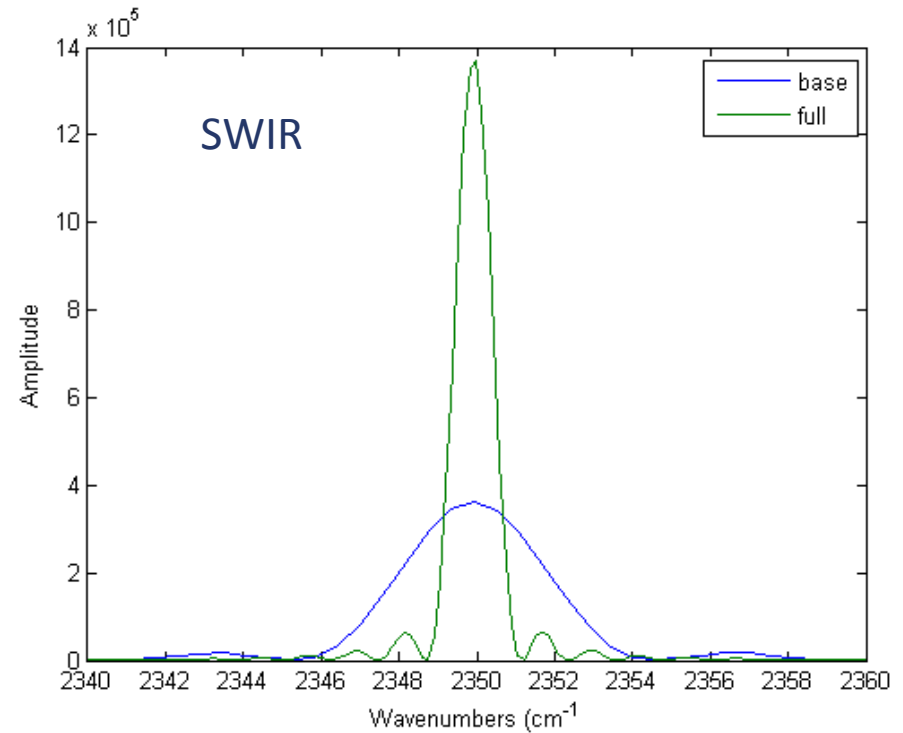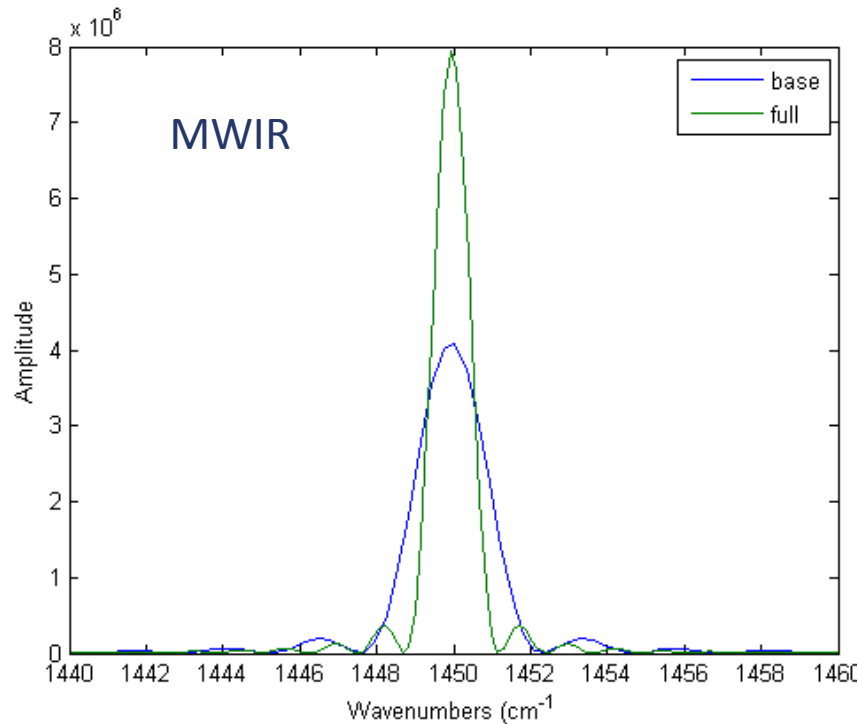
- **Increased spectral resolution clearly demonstrated**
- **Diagnostic mode interferograms**
- **Magnitude spectra with triangle apodization**

# Full Spectral Resolution Test Performed during Spacecraft Thermal Vacuum Testing

- **During Hot Plateau 4, CrIS was commanded to full spectral resolution mode**
- **More than two hours of full spectral resolution data were collected**
- **Higher spectral resolution for MWIR and SWIR were verified**
- **No data dropouts or other data problems were observed**
- **NEdN increase was consistent with the higher number of spectral bins**
- **Higher data rate is easily accommodated by the spacecraft**
  - Data rate lower than normal mode diagnostic mode
- **No problems in reconfiguring CrIS back to normal lower-resolution mode**

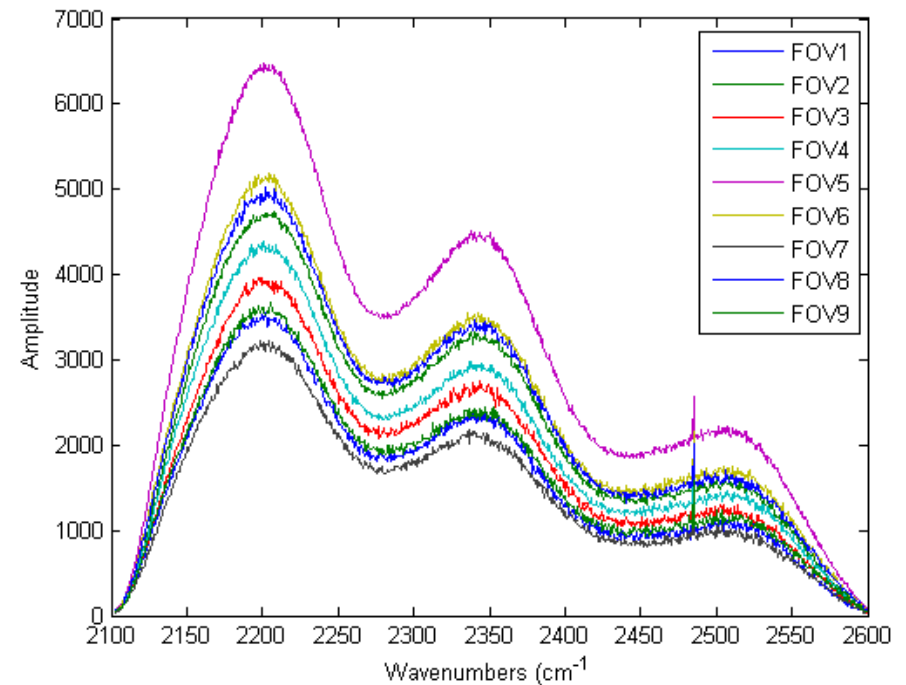# MW Full Resolution Test, No Calibration
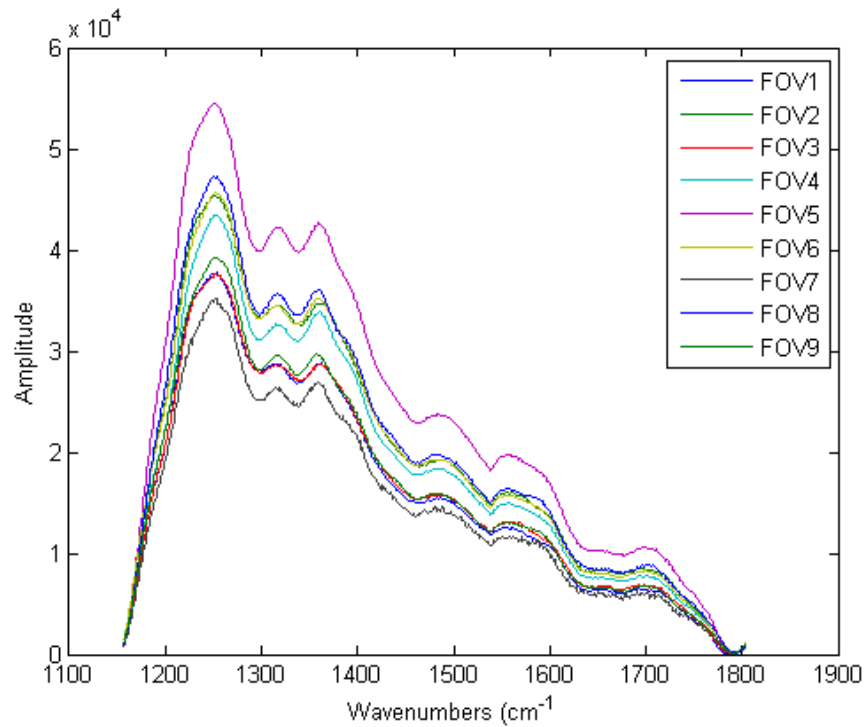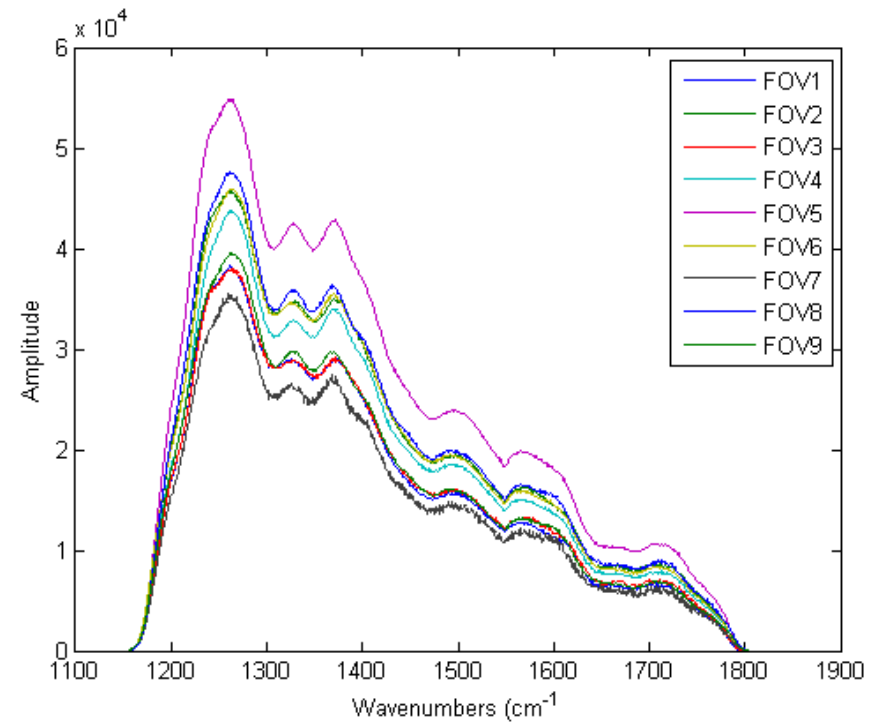
Normal Resolution

Full Resolution
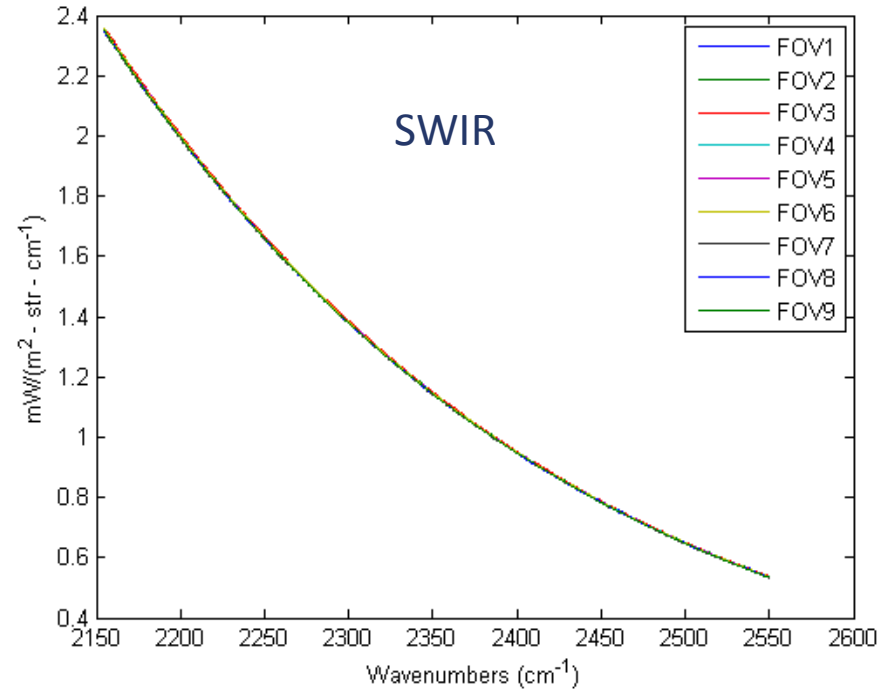
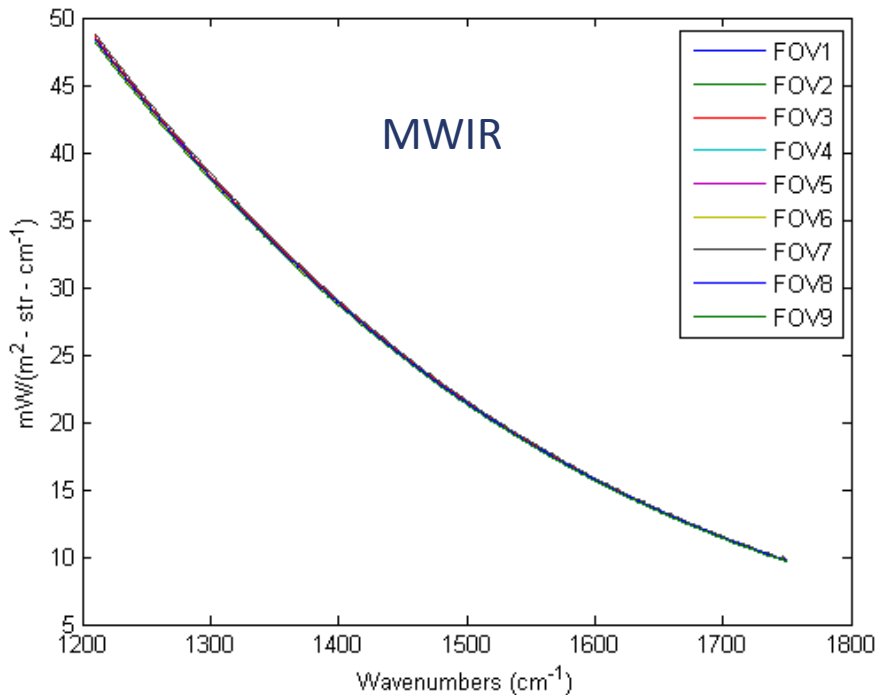# SW Full Resolution Test, No Calibration
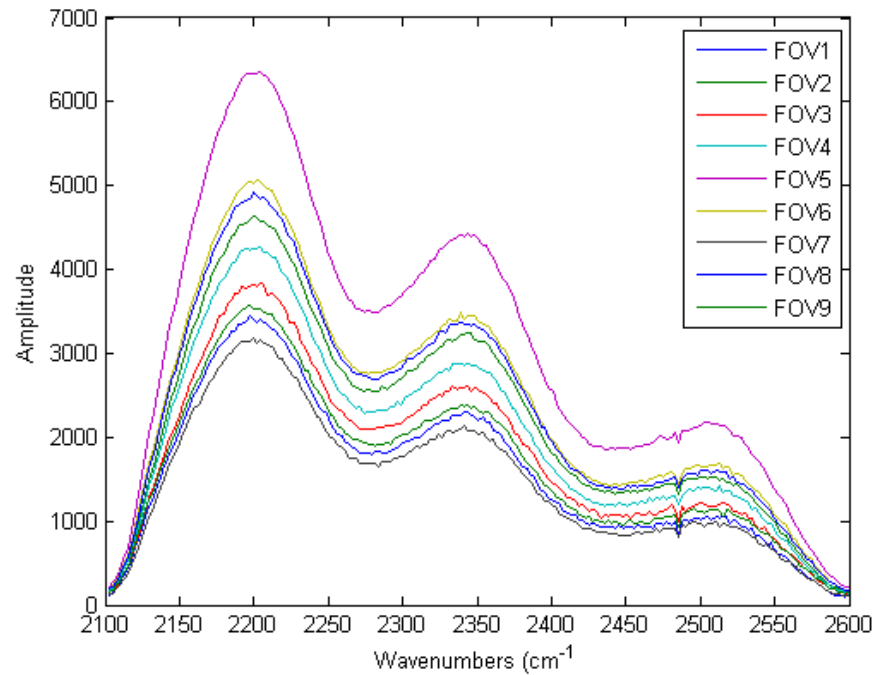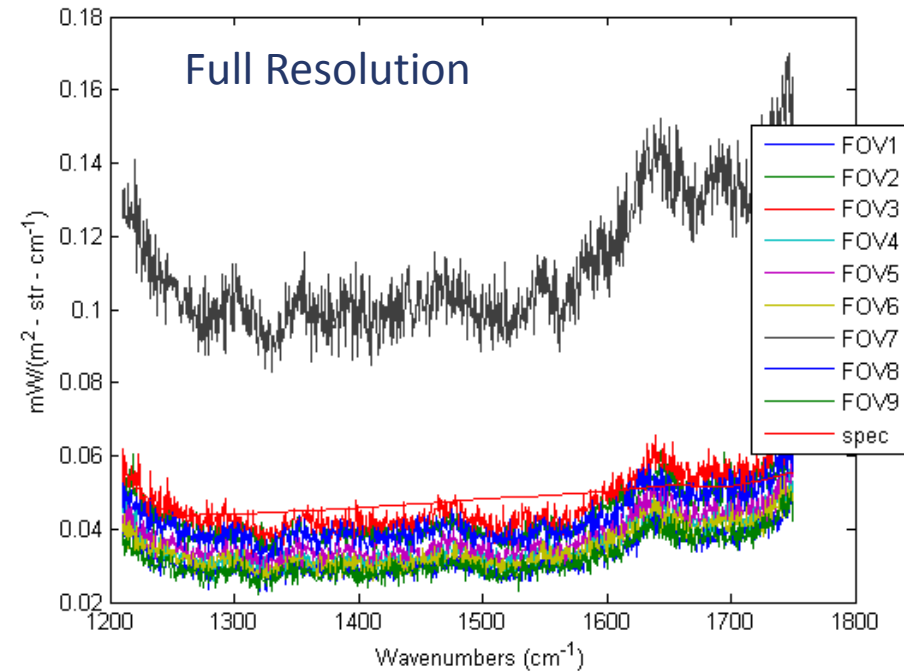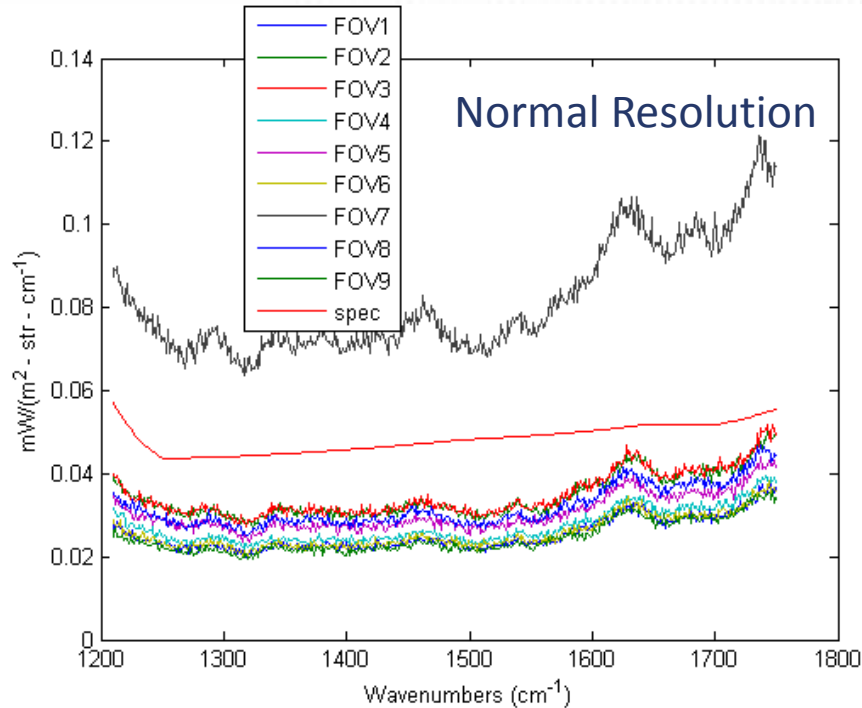

Normal Resolution

Extended Resolution

Calibrated Radiances

- **Ground-based SDR software requires modification to process full resolution data**
- **Calibration process works as expected using compatible calibration software**
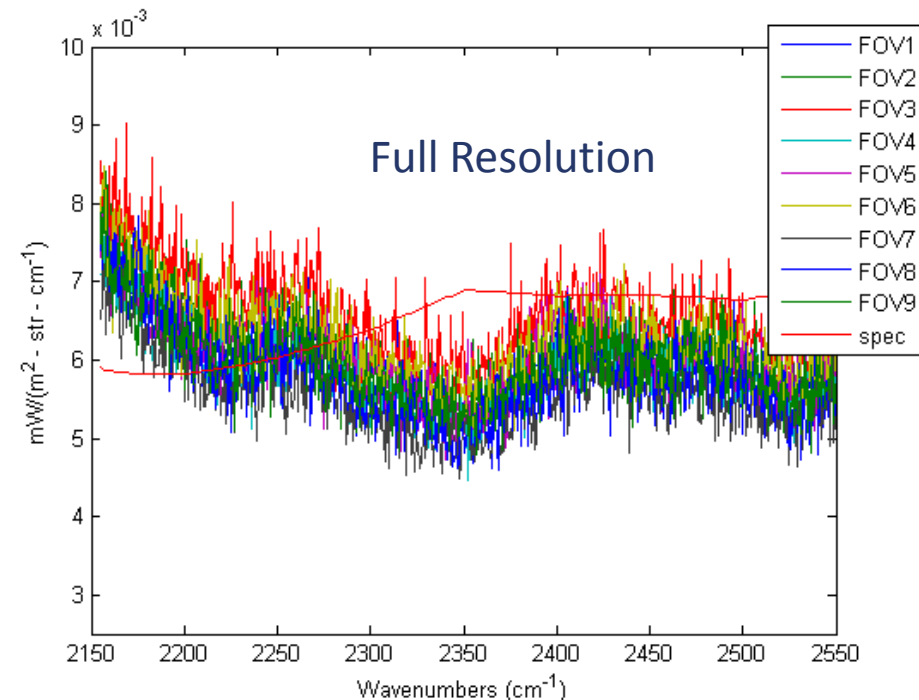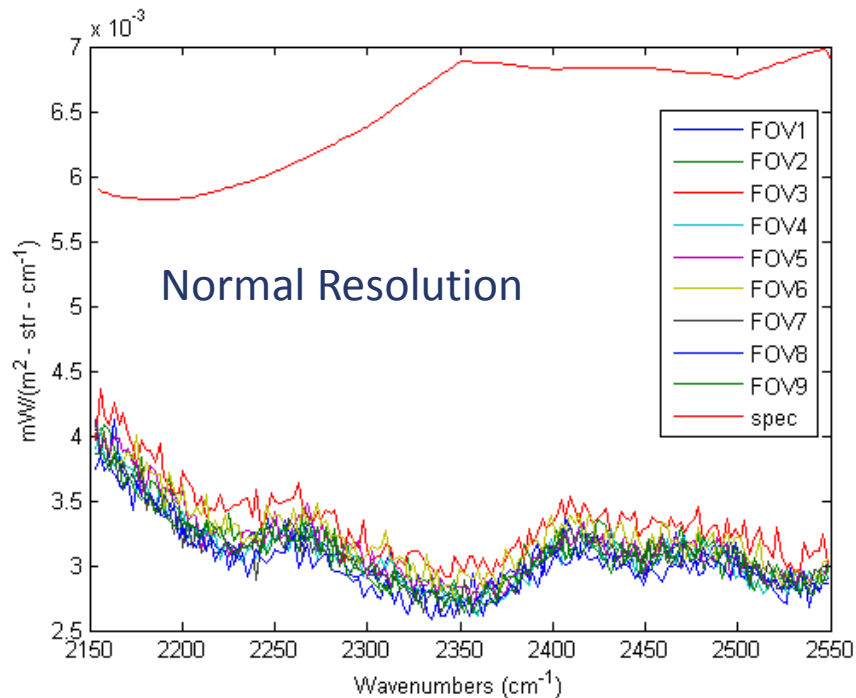
MWIR NEdN

Normal Resolution

Full Resolution

- ❯ **MWIR NEdN increased by a factor of $\sqrt{2}$**

- ❯ **For constant mirror drive speed, the increase in NEdN is proportional to** $\sqrt{\dfrac{res_{old}}{res_{new}}}$

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SWIR NEdN

Normal Resolution

Full Resolution

- ❯ **SWIR NEdN increased by a factor of 2**
- ❯ **Spectral regions that do not have spectral structure can get NEdN back by averaging**

Full Resolution Interferogram Processing

> During the Spacecraft TVAC Hot Plateau 4 test full spectral resolution interferograms were collected

> The current version of the ground processing software can not process full resolution interferograms for the MWIR and SWIR

> SDL developed a Matlab tool to convert full spectral resolution interferograms to the standard resolution NPP interferograms

> These truncated interferograms can then be processed into spectra with the standard spectral processing software

> The following two slides show a comparison between spectra from the truncated interferograms and the standard NPP interferograms

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RU From Truncated Interferograms
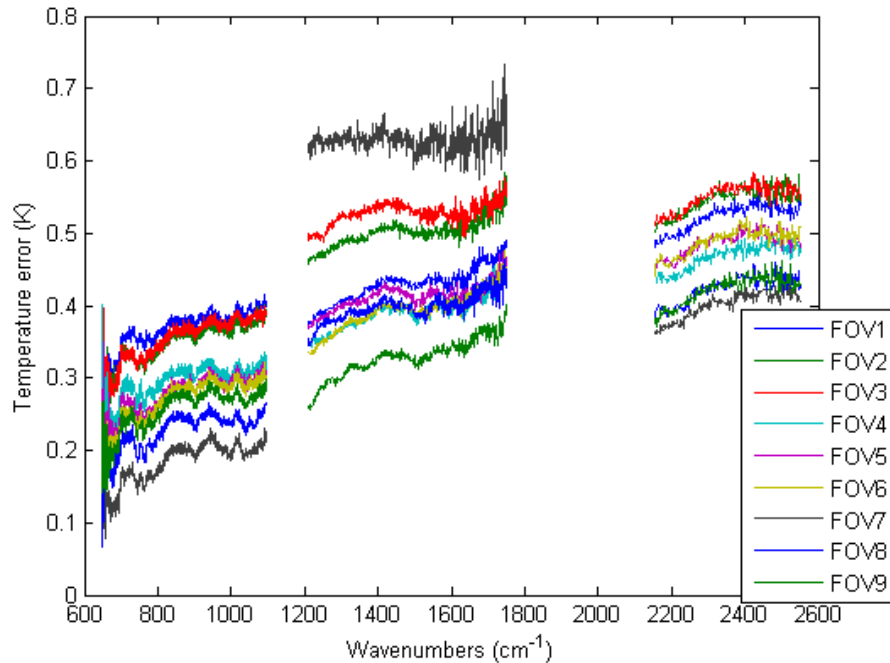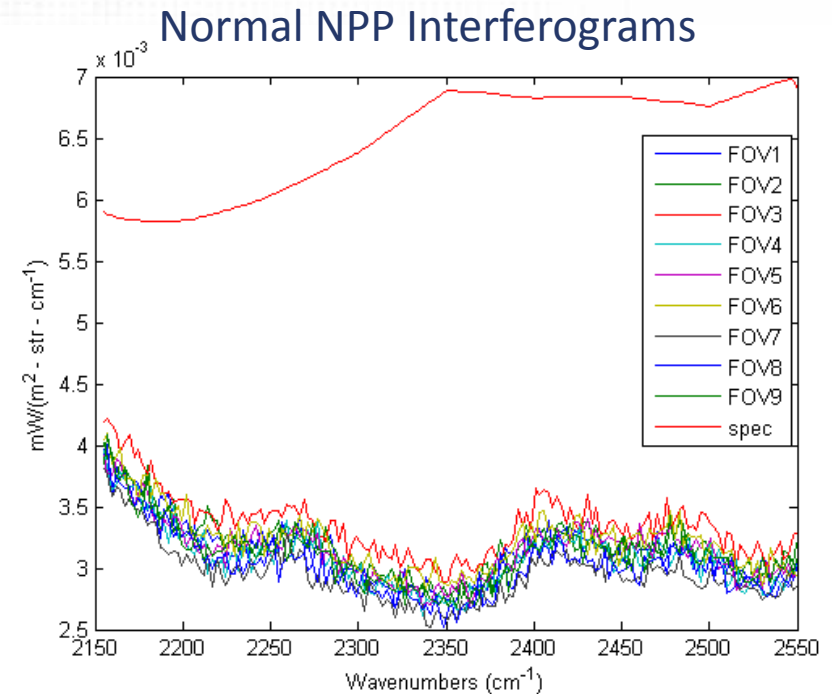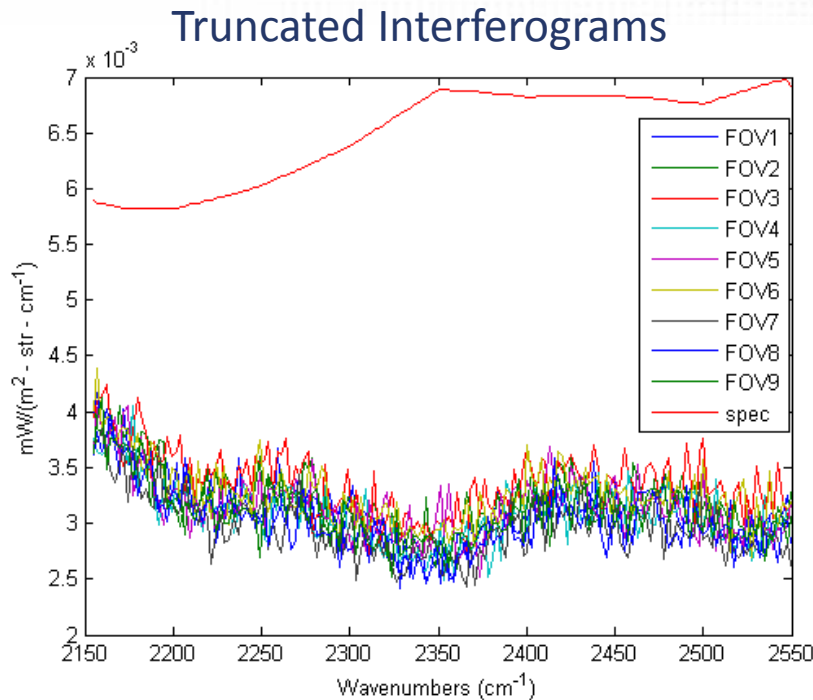
Truncated Interferograms   Normal NPP Interferograms
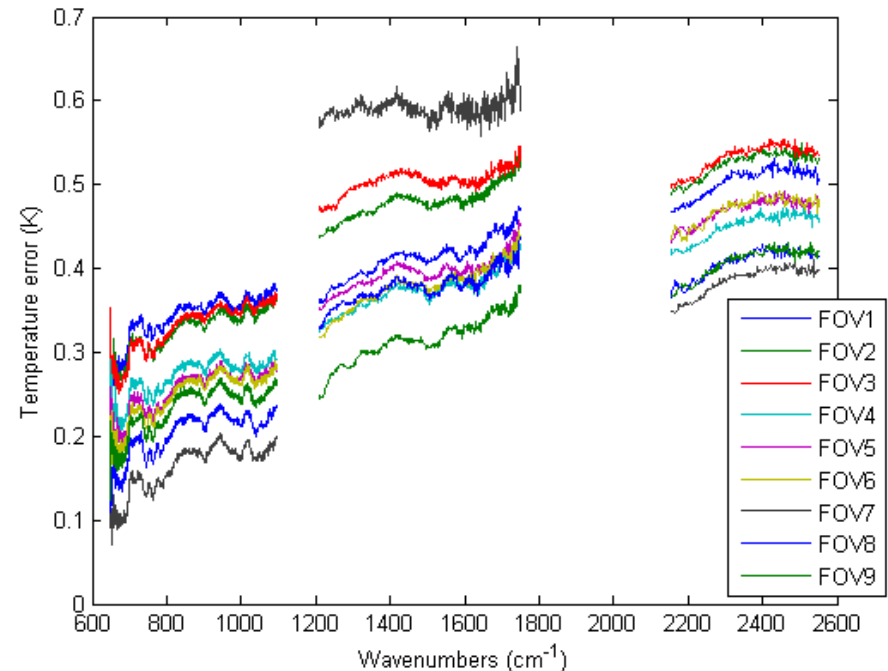
> **Radiometric Uncertainty (RU) is the difference between the measured spectra and the ideal spectra**

> **Truncated interferograms result in spectra that are essentially the same as normal mode interferograms**

NEdN From SWIR Truncated Interferograms

Truncated Interferograms

Normal NPP Interferograms

› **NEdN is the standard deviation of a set of spectra**

› **Truncated interferograms result in spectra with essentially the same NEdN as normal mode interferograms**

Conclusion

› **CrIS can produce full spectral resolution data in all bands with no hardware or flight software changes. Simple table uploads are all that is needed to transition CrIS to full resolution mode.**

› **Higher spectral resolution would remove risk of uncertain spectral calibration of the SWIR and provide continuity of atmospheric chemistry time-series established by the NASA EOS program.**

› **CrIS full spectral resolution was demonstrated by test at ITTExelis and at Ball Aerospace.**

› **In the event of an unforeseen problem, simple uploaded commands can restore CrIS to the baseline lower spectral resolution mode.**

› **Program-level planning is now needed to best utilize this enhanced CrIS capability.**

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